WATER MAIN CLEANING IN KANSAS CITY, MISSOURI[1]

By Charles S. Foreman[2]

Water works engineers and superintendents usually know the necessity of cleaning certain water mains or feeder mains in the system which they may be operating, but before they are able to obtain authorization and appropriations to cover such work, they are called upon to answer many questions which may be brought up before a board of commissioners. The author believes that the publication of his experiences in water main cleaning in Kansas City during the past three years will be of value to other water works superintendents desirous of instituting similar work in the systems under their jurisdiction and that the following essential facts based upon his experiences will help to answer some of the questions which are usually asked.

1. The cleaning can be so arranged that a main need not be out of service longer than 12 hours for cleaning.
2. The cleaning process is not injurious to the mains.
3. An increase in carrying capacity of from 60 per cent to 85 per cent was obtained in large mains, and the carrying capacity of such mains was restored to that of new pipe.
4. The saving in coal costs alone, derived from cleaning, will pay the entire cost of cleaning within from 1 to 3 years.
5. The laying of additional mains to obtain increased capacity can be postponed until the consumption demands are equal to the maximum capacity of the old main on the basis of new pipe.
6. When taking as credits such items as coal saving and postponement of obligatory laying of new mains, the entire cost of cleaning is saved within from 6 months to 1 year.

In Kansas City, Missouri, for 2 or 3 years prior to the summer of 1918, there was always a lack of adequate pressure in the north and east portions of the city. This district is fed from the Turkey

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[2] First Assistant Engineer, Water Department, Kansas City, Mo.

Creek pumping station through one 20-inch and one 30-inch cast iron water main. Laying additional feeder mains into these districts was abandoned because of the exceedingly high prices of material and the lack of funds. Therefore the proposition of increasing the carrying capacities of the old mains by the cleaning process was resorted to in the fall of 1918.

Tests were run on the 30-inch high pressure discharge line extending from Turkey Creek station to 17th and Baltimore Streets, a distance of approximately 6000 feet, for determining the interior condition and carrying capacity of this pipe, which was laid in 1886. The tests were made by making taps exactly 1000 feet apart upon a straight length of the main, there being no services or connections to the main between the gauging points. At each of these points 1-inch corporation cocks were installed for inserting pitometers and additional corporation cocks for pressure lines. A 2-inch pipe was connected to each of these taps, and 1000 feet of this pipe was laid along the surface of the ground, bringing the two together so that a U-tube could be connected in to measure the differential pressure between the two points. The 30-inch pipe was double traversed at each end pit and the average traverse coefficient obtained. A pitometer was then set at each pit for checking quantities flowing through the 30-inch main.

The scale on the differential U-tube was graduated in 0.01-foot divisions, and by using a liquid of specific gravity of 2.00 in this tube the readings obtained were in feet loss of head per thousand feet.

The advantages inherent in this method are that it is not necessary to obtain the difference in elevation between the two points, and that it eliminates the use of spring gauges. Piezometers could not be used because of the high pressure, all of the lines being under pressures of 125 to 150 pounds per square inch.

The pipe and connections for bringing the two pressures to the differential U-tube should be water-tight for accurate results. No difficulty was experienced in making them up tight. With pipe of $1\frac{1}{2}$ to 2 inches diameter, a slight leak did not materially effect the results.

The test extended over a 24-hour period so that both maximum and minimum velocities in the pipe could be obtained. The result of this test is shown graphically in figure 1.

It will be noted that the average pipe coefficient, as computed by the Williams and Hazen formula, was 69.69, this being lower than

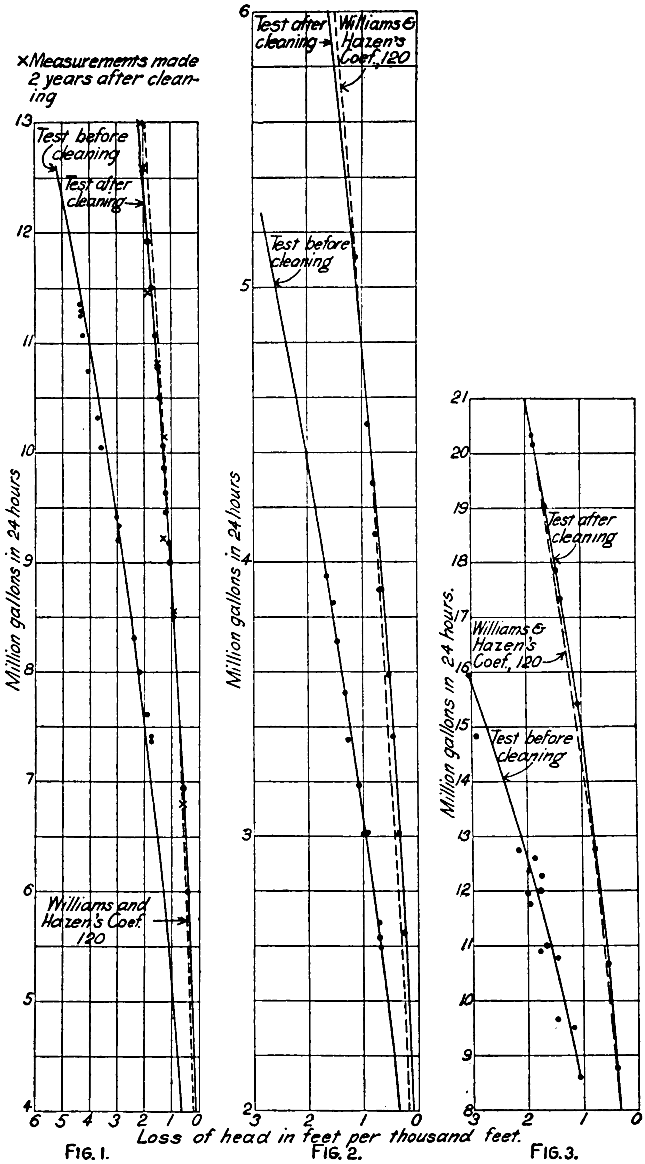

FIG. 1. TESTS OF 30-INCH HIGH PRESSURE MAIN
FIG. 2. TESTS OF 34-INCH HIGH PRESSURE MAIN
FIG. 3. TESTS OF 36-INCH FLOW LINE

	30 inch	34 inch	36 inch
Average diameter, after cleaning...	2.003	2.494	2.991
Area, before cleaning...............	3.1353	4.844	7.0266
Area, after cleaning................	3.151	4.885	7.0266
Ave. traverse coef., before cleaning	0.73	0.708	0.74005
Ave. traverse coef., after cleaning..	0.823	0.827	0.8584
Ave. pipe coef., before cleaning....	71.864	69.69	71.5
Ave. pipe coef., after cleaning.....	121.64	115.9	122.33

that in the Williams and Hazen tables for pipe 40 years old. From these tests it was evident that the 30-inch line was far below the carrying capacity of new cast iron pipe. A contract was awarded to the National Water Main Cleaning Company for the cleaning of 6000 feet of this 30-inch pipe.

Similar tests were run after the pipe had been cleaned and the results are also shown in figure 1. The average pipe coefficient was brought up to 116, and at low velocities, as high as 120, the carrying capacity of this pipe having been restored to nearly that of new pipe.

The cleaning of the 30-inch pipe gave such excellent results that a contract was let to the same company for the cleaning of additional feeder mains into the northeast section of the city, there being 30, 24, 20 and 16-inch pipe lines in this contract.

Similar tests were run on each of these pipe lines both before and after cleaning, and the results of some of them are shown in figure 2. In all of these cases, the pipe after being cleaned was restored to the carrying capacity and corresponding loss of head indicated in Williams and Hazen's tables under coefficient 120.

In making the test on the smaller lines, it was not practicable to place the gauging taps 1000 feet apart because of service connections and connections at street intersections. They were placed 200 feet, 250 feet and 500 feet apart, depending upon conditions encountered.

The liquid used in the differential U-tube was a mixture of carbon tetrachloride and bromoform brought to the required specific gravity by the addition of gasoline. The specific gravity was varied in accordance with the variation in distances between the taps on the line to be tested, so that in each case the readings on the U-tube were directly in feet loss of head per thousand feet.

In the spring of 1919, similar tests were made on the 36-inch flow line from the low-service station at Quindaro to the Kaw River tunnel, a distance of 17,000 feet. It was found that the average pipe coefficient as computed by the Williams and Hazen formula was 71.5 and that by cleaning this line the coefficient was restored to 122.33. See figure 3.

The methods used by the National Water Main Cleaning Company for cleaning large mains leave for the Water Department no intricate or expensive coöperative work. The section of pipe to be cleaned is valved off and a cut made at each end sufficient to admit entering and removing the cleaning machine. After cuts are made

and the machine inserted, the pipe is then sleeved up and the joints poured, after which the water is turned on behind the machine. After the machine once starts moving, it travels very rapidly through the main (3 to 4 feet per second), coming out at the open end of the section to be cleaned and bringing all the dirt and encrusting material out ahead of it.

The actual time any section of main is out of service depends almost entirely upon the speed which can be made in making the necessary cuts in the pipe and sleeving them up, as the actual traveling of the machine from one end to the other of a section of pipe requires but very little time. Usually the cuts on large mains can be so arranged that they can be made and repaired in approximately 12 hours, so that it is only necessary to have the main out of service for that length of time.

The actual cutting and repairing of the various mains was done by department forces, while all of the other work, such as excavating, backfilling, and placing of machine, was done by the contractor.

The contractor's price for cleaning ranged from 26 cents per foot for 16-inch pipe to 45 cents per foot for 36-inch pipe and the total cost, including all expenses for operating valves, cutting and repairing pipe and for all necessary sleeves and material, was $22,046.09 for 43,837 lineal feet of pipe cleaned, or 50.3 cents per lineal foot for all sizes.

The total cost of cleaning the various sizes, including pavement repairs and operation of valves, etc., was as follows:

7,202 feet of 16-inch pipe, $2,472.52 or 34.3 cents per lineal foot
7,280 feet of 20-inch pipe, $3,056.80 or 41.9 cents per lineal foot
3,371 feet of 24-inch pipe, $1,813.56 or 53.5 cents per lineal foot
8,984 feet of 30-inch pipe, $5,604.93 or 62.3 cents per lineal foot
17,000 feet of 36-inch pipe, $9,098.28 or 53.5 cents per lineal foot

Referring again to figure 1 the average flow through the 30-inch pipe from Turkey Creek Station to 17th and Baltimore Streets before cleaning was 11,100,000 gallons per day and the friction loss was 4.23 feet per thousand feet. After being cleaned, with the same quantity of water passing through the pipe, there was a friction loss of 1.6 feet per thousand feet or a net gain of 2.63 feet per thousand feet, amounting to 15.78 feet for a total of 6000 feet cleaned. This was also checked approximately with pressure gauges at each end of the line and is equivalent to a saving of 1,460,000,000 foot-pounds of work per 24 hours.

Had this been a line through which it was desired to deliver 11,100,000 gallons of water per day at a certain head, there would have been an actual saving in coal of $6.67 per day or $2,435 per year, so that the saving in 1 year of coal alone almost equals the cost of cleaning.

However, as a constant station pressure of 150 pounds is carried at Kansas City, the cleaning resulted, either in increasing the pressure in the downtown district 15.78 feet with the same quantity of water passing through the line, or with the same loss of head as before cleaning, the quantity delivered through the line would be approximately 19,500,000 gallons per 24 hours, or an increase in carrying capacity of 8,400,000 gallons per day or nearly 80 per cent.

To obtain the same increase in capacity as the cleaning of the 30-inch pipe resulted in, would mean the laying of an additional 24-inch feeder main. The estimated cost of such a line at that time was $88,800 and the annual interest on this amount at 5 per cent is $4440, making a total annual saving of $6944 as against a total total cost for cleaning of $3720.50.

In the case of high pressure distributing mains, the cleaning of the 26,000 feet of various sized pipe now permits the delivery to the northeast section of town of approximately 12,000,000 gallons per day more water than before cleaning without increased head at the pumping station. Therefore it will be readily seen that the laying of additional feeder mains can be postponed for some time by keeping the present feeder mains up to their maximum carrying capacity.

In the case of the 36-inch flow line, it was found on the test before cleaning that with a loss of 2.7 feet per thousand feet the line was flowing 16,000,000 gallons per 24 hours. This was practically the maximum amount of water that it was possible to put through this line with the limiting head of 50 feet on the Quindaro pumps. The test after cleaning indicated that with the same loss of head, the capacity had been increased to approximately 26,000,000 gallons or 75 per cent.

In other words, this gave the department an increase in flow-line capacity of approximately 10,000,000 gallons per day, which was greatly needed during the periods of maximum consumption in the summer of 1919. Under normal conditions of consumption, the cleansing of this flow line actually resulted in a saving of 1.7 feet of friction loss per thousand feet.

Table 1 shows the length of time in service, the annual operating cost for coal, before and after cleaning of the various sizes cleaned. Also the investment required and the annual interest thereon to obtain the increased capacity by laying new mains and the total annual saving, all being based on 5000 feet of each size and on the normal flow through the pipe at time tests were made.

Inspection of the interior of the mains after cleaning discloses that the machine had no injurious effect upon the interior surface.

TABLE 1

Annual costs and saving before and after cleaning on basis of 5,000 feet of each sized pipe

SERVICE YEARS	SIZE	M. G. D. NORMAL FLOW	LOSS OF HEAD PER 5000 FT.		ANNUAL COAL COST TO OPERATE LINE		ANNUAL COAL SAVING	SIZE REQUIRED TO OBTAIN INCREASE IN CAPACITY IF NOT CLEANED	ESTIMATED COST 5000 FT.	INTEREST ON EXPENDITURE 5 %	TOTAL ANNUAL SAVING	TOTAL COST OF CLEANING.
			Uncleaned	Cleaned	Uncleaned	Cleaned						
	ins.							*ins.*				
41	16	2.4	24.00	7.50	$462.53	$144.53	$318.00	12	$27,200	$1360	$1778.00	$1715
42	20	3.4	23.50	5.60	641.60	152.89	488.71	16	33,100	1655	2143.71	2095
28	24	5.0	12.60	5.25	505.90	210.79	295.11	16	33,100	1655	1950.11	2675
33	30	12.0	23.50	9.00	2264.46	867.24	1397.22	24	70,000	3500	4897.22	3115
33	36	16.0	15.25	6.00	3740.52	1471.68	2268.84	30	73,500*	3675	5943.84	2675

Annual cost for fuel to pump one million gallons one foot high at Quindaro = $0.042.

Annual cost for fuel to pump one million gallons one foot high at Turkey Creek = $0.022.

* No pavement or rock.

Surface supply, Missouri River water.

The springs on the machine are not set stiffly enough to cut into the cast iron and in many instances where inspection was made, it was found that the old tar coating was still in the grains of the iron. The machine in many instances was sent around sharp curves, some as sharp as 60-degree bends, and also through open gate valves, without injurious effect. It cleans the walls of the pipe very thoroughly and leaves it practically as smooth as new pipe.

As to the question of how long the benefits derived from the cleaning of water mains may be expected to last, the author has heard

it stated many times that after a pipe had once been cleaned the corrosive effect or the formation of tubercles was very much more rapid than before cleaning. In fact, the contractor stated that the carrying capacity might decrease the first year but would be less rapid thereafter. With a view to ascertaining what this effect would be on the 30-inch main, permanent pitometer pits were put in so that tests could be run from time to time after the cleaning. Accordingly pitometer and loss of head tests were run again in the fall of 1920 on this main and the results of these tests are also shown graphically by the crosses in figure 1. It will be noted that two years after cleaning, there was practically no change in results from the test run immediately after the pipe was cleaned. This would indicate that the corrosive action is no faster after cleaning than on ordinary new pipe.

The author believes that in designing and laying new feeder mains, serious consideration should be given to the advisability of building permanent pits with removable sections of flanged pipe so that a main can be readily and cheaply cleaned from time to time.

It is now the common practice among engineers, when computing the size of pipe required to deliver a certain quantity of water, to use the loss of head figures given in Williams and Hazens tables under coefficient 100, thus providing a larger size than necessary under coefficient 120. It can be readily seen that the interest on the saving in first cost between the smaller and larger pipe will far more than pay the cost of maintaining the smaller pipe at its maximum capacity by cleaning it whenever necessary.